A new generation of two stroke engine

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ABSTRACT

Team QUIETS is very proud to take part in this year's Clean Snowmobile Challenge hosted by Michigan Tech University. Team is bringing the same sled we used last year, a 2-stroke 600cc MXZ Rev from Bombardier, with some major modifications. With the experience acquired from last year's event, the team comes up with some new ideas and is eager to see how good the snowmobile will perform throughout the multiples challenges. In the present technical paper, you will see what modifications were made and the different reasons why they were made.

INTRODUCTION

Since the creation of the snowmobile in 1960 by J-Armand Bombardier in Quebec, Canada, this product knew a quick popularity throughout the country and North America. With an annual average snowmobile sale in Canada of more than 57000 units on the last twelve years, this winter sport as an important economic impact. In Canada only, this sport generates $6 billion annually. This situation is proportionally the same in the province of Quebec. Each year, about 800000 persons practice snowmobiling throughout Quebec and its also an appreciate activity by tourists by this way the total direct economic repercussions are estimated at 752 M$.
However, all this circulation involve significant consequences. Since december 1st 2004, the court of Quebec ordered a judgement prohibiting the snowmobiles on approximately thirty-eight kilometers in the Mont-Tremblant area on the linear parc of “Le Petit Train du Nord”. This legislation came from complaints of owners, living a few hundred meters away from the path, that consider unacceptable the noise emitted by the snowmobiles everytime of the day [4]. This judgement had big consequences on the snowmobile tourism industry and several jobs were in danger.

To resolve this situation and to assure the survival of the region winter tourism, new technological solutions must be used. Those solutions must provide the enthusiasts with good performances while being environmentally friendly.

Since 1998, to help improve and find innovative ideas for the snowmobile world, the Society of Automotive Engineers organizes each year the Clean Snowmobile Challenge (CSC). This competition is opened to colleges and universities in North America. The goal is to modify an existing standard snowmobile to make it more ecological, mainly by reducing its fuel consumption, the levels of pollutants and reducing the noise emitted by the sled. The students must also keep good performances to keep a certain appeal to consumers. This year, the CSC will be held for the 3rd year in a row in Michigan's Keweenaw Peninsula from March 14 to 19. To represent the Quebec, the QUIETS from the “École de Technologie Supérieure” in Montreal will be participating for its third year at this challenge.

In mind to participate to the Clean Snowmobile Challenge 2006, team QUIETS has to work hard to realize modifications to the sled. The team member don't receive any credit for the project, they are considerate as a not-lucrative company. To realize their achievements, each member was looking for different companies sponsorship by developing a technological partnership with them.

The following paper describes in details the modification made to the sled and why those modifications were made. The first section describes how the team was able to keep a maximum performance while making important changes. Secondly, the emissions section explains the technologies used to reduce harmful exhaust pollutants. The next section is about noise reduction and the different systems used to achieve our goal. Finally, a small analysis concerning the overall costs of all our modifications is concerning. In the end, the sled proposed by team QUIETS is economical, reliable, performant, environmentally friendly and is a good contender in the 2005 CSC.

PERFORMANCE

THE ALTERNATIVES – By talking with snowmobilers, we found which characteristics we were going to focus on when working on our sled. All the people are convinced that the power, the torque and the acceleration of the snowmobile are the most important things. The competition needs us to develop a balance between environment and consumer's demands. How could we make this? First of all, we have to analyze what technologies are available that offer power, that are light weight and have good noise and pollutant emissions.

- Two stroke engine
- Four stroke engine
- Two stroke semi-direct injection engine
- Two stroke direct injection engine
- Diesel compression technology

The 2-stroke engine is the best engine based on power to weight ratio. It has a good acceleration and powerful torque. However, the biggest problem with the two-stroke engine is certainly its level of pollution. The snowmobile emissions test clearly shows that the 2-stroke engine pollutes more than the 4-stroke.

	grams/HP/Hour			
Engine	HC	CO	NOx	MP
2 stroke	111	296	1	2,7
4 stroke	8	123	9	0,2
2stroke DI	22	90	3	0,6

Table 1: Combustion gas chemical composition. [5]

This study presents a different type of engine called 2-stroke DI. DI meaning direct injection. It suggests that this new technology will reduce emission from 25 to 35 percent inferior than those of a 4-stroke engine. This process is now available on marine engines and watercrafts and they surpassed the 4-stroke standards. The 4-stroke has a lot of advantages too. It is reliable and as low pollutant emissions which make it a good choice. After examining all the information for every engine, we decided to base our modifications on the consumer's and environmentalist's demands.

CHOOSING OUR MOTOR – With all these alternatives, to make the ideal choice is not easy. Each engine has advantages and disadvantages. We can base our choice on several different criteria like the pollutant's emissions, average fuel consumption, the noise level of the engine, its reliability or its performance. We needed to take a logical decision that represented today's snowmobile market and choose an engine that represented the choice of the snowmobile owners. This choice could have more impact on bringing technologies further in snowmobile. We prefer this orientation rather than to invent a new engine or to use another form of energy to move this machine. Thus, we discovered in our research that the most popular engine sold in snowmobile these last years is in the range of the 2-stroke 500 cc.[6] With this second criteria, we could eliminate some engines that we talked about earlier. We continued our research and we found a survey that shows the more important aspects that the snowmobilers consider at the time to purchase a news sled. Here are the results of this survey:

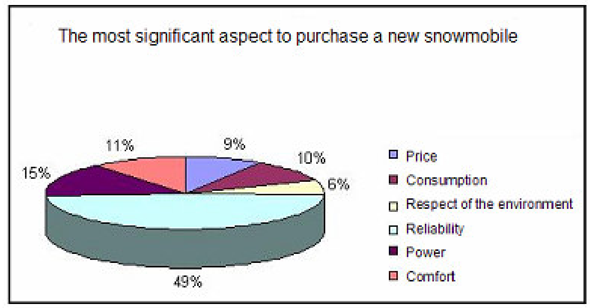


Figure 1: Criteria that guide the consumer's choice for a snowmobile.

However, by taking account only of the two following criteria: power and reliability, there are 2 engines which are dissociated more than the others; the engine 2 times and the engine 4 times. Thus, to make a more exact decision we compared these two engines on the characteristics than we knew about these 2 engines. Here what is come out from these engines [7] :

4-stroke:

- Reliable
- Low power/weight Ratio
- Clean Emissions
- Less fuel consumption
- Harder maintenance
- Present in snowmobiles since 1960
- Quiet
- More advanced technology

2-stroke:

- Less reliable
- High power/weight ratio
- Not very clean emissions
- High fuel consumption
- Easy maintenance
- Present in snowmobiles since 1960
- Noisy
- Simple technology

With this information, the choice of the 2-stroke engine is more favorable since it is this type of engine which one finds more on the market. However, this engine does not really satisfy the criteria of the competition. To support this choice, here is a study [8] that shows the advantages of 2-stroke DI compared with a 4-stroke engine (another possible alternative). This comparison is made with two similar engine operating in the same conditions.

- The 2-stroke engine with direct injection is 30 % lighter, 30 % less expensive, 30 to 40 % less cumbersome and up to 50% more powerful than the 4-stroke engine.

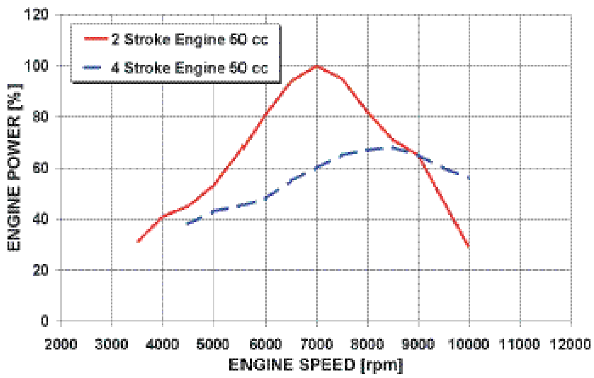


Figure 2: Percentage difference of the effective power of the GDI two-stroke and a series four-stroke engine.

Thus this type of engine offers the following advantages:

- It respects the levels of antipollution regulation at the same cost price as the 4-stroke, even less...

- It becomes more suited than a 4-stroke engine to accept tighter levels of anti-pollution (4-stroke is penalized by its NOx and CO emissions).
- It emits less visible smoke.
- Its fuel consumption is 10 to 20 % smaller than the 4-stroke with of the same carburetor capacity.

<u>Our final choice</u> – Finally, to meet all the criteria that will be used to evaluate the sleds during the CSC, that is, consumption, the pollutant emissions, the noise and the performances and to respect our own pre-established criteria, we decided to use the a Rotax 2-stroke 600 cc HO from Bombardier.

Figure 3: Rotax 600cc two-stroke engine for Bombardier.

However, this is a bold choice of engine. Several studies prove that it is the worst enemy of the environment. Isn't this a true challenge? While making it cleaner? To be able to obtain results known as ecological and in the light of the data showed above, the engine will be equipped with a direct injection system.

INJECTION – (…) We can affirm that direct fuel injection is the technology preferred to reduce in a permanent way and substantially the consumption of fuel and the emission. (…)

These are the conclusions of Patrice Seers Phd. Direct fuel injection do produce a better complete combustion, comparatively to semi-direct injection on every other intern combustion engine, particularly on 2 stoke engines, because the admission ports and the exhaust port are open at the same time. To include this new technology in our vehicle, we have to choose the parts more convenient to our needs. With this in mind, our injection system comes from a 4 stroke engine, even though there is direct injection system for 2 stroke engine on the market. On the opposite, those systems requires superior air pressure, thus needing a mechanical pump driven by the engine to insure the exhaust fumes are cleared from the combustion chamber by the counter-pressure, because the injection is done while the piston is coming up and the exhaust port is completely open, the air pressure pushing on the fuel must be superior to the air pressure present in the cylinder. It is possible to use normal air pressure to clear the fuel from the combustion chamber is the fuel pressure is superior to the one in the combustion chamber, which needs a very high fuel pressure. With this compressing air needs parts, not normally installed on a standard snowmobile, because the fuel pump are rarely built to produce pressure superior to 65 PSI, which is not sufficient for injection, because the pressure in the cylinder during the admission phase is 112 PSI. On top of that, the power circuit of a snowmobile isn't powerful enough to supply the current to power a fuel pump that can push this pressure because those function on 12 V, 15 amps. Considering the energy the magneto of a standard snowmobile can generate, it is necessary to supply a mechanical pump to produce 130 PSI of fuel pressure. The space in the snowmobile cab is very small, the pump must be compact too. Our choice was an aeromotive #11107, driven by a pulley belt. This pump is very compact but is also very powerful. The pump can deliver pressure up to 200 PSI, with a flow of 2700 pounds an hour, which is more than enough for our application. With this fact in mind we had to rebuild our fuel line to resist that kind of pressure.

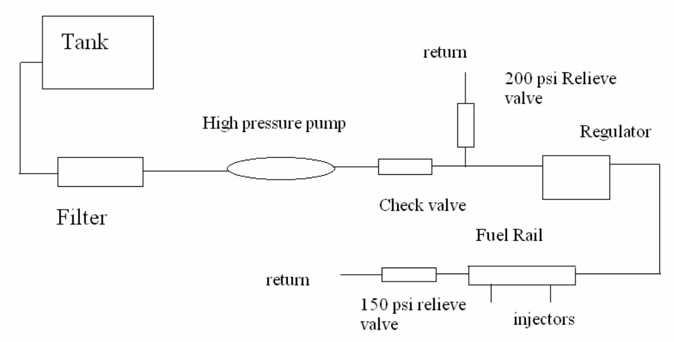


Figure 4: Fuel line set-up

This new system which is made from steel, includes a check valve to avoid a drain back pressure to the pump and maintain the pressure in the line when the snowmobile is not working. It also helps on the restart because the pump doesn't have to rebuild pressure every time. The system also includes a pressure regulator. That will insure a constant flow and pressure in the line and increase the security level. The fuel line would have to include relieves valves, with an overflow coming back to the fuel tank, because the pump is driven directly by the engine, which means all the fuel pumped must be used by the engine, if not, the pressure would build up dangerously, up to a point where it can break apart. This is why the maximum pressure is set to 200 PSI. The admission system must have a fuel filter to insure no unwanted particles reach critical areas, damaging part like injectors which are easily clogged.

Thus, the major component to modify is the engine's head. The initial position of the spark plugs on our engine is at center of the cylinder (Sees pictures xx). With the injection system, the injectors and the spark plug make an angle of 30° with a vertical axe. This new configuration causes a lot of problem to keep the functionality of the engine. To eliminate this problem we decided to design a new engine's head. With this design, we are sure that the position of the components is right and that the sealing is preserved. Here is the new engine's head:

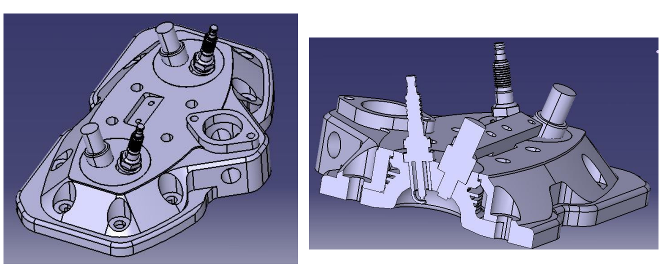


Figure 5: The new engine head design.

Finally, to drive fuel injectors, a computer is necessary. Last year at the competition, we had an injection system drives by a Haltech controller. It stills the same use for this year. This characteristic permits to keep performance of the engine in higher revolution.

KEEPING THE PERFORMANCES – To keep the eye on the track and give some challenge this year, the 2-stroke DI engine is the symbol of power and ecology. To achieve some pollution standards, we're going to use the new DI technology. This new stuff is applied on outboards engines. The tight rules of California forced the manufacturers to develop special features. The Nissan TLDI and the Bombardier Sea-Doo, both DI two-stroke engine, surpass the EPA and CARB(California Air Resources Board).

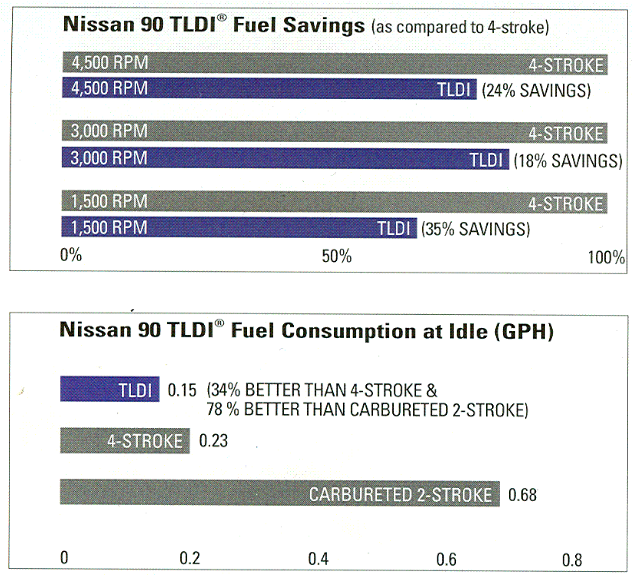


Figure 6: Comparison table of a Nissan TLDI and a standard 4-stroke engine.

But the injection is not the only thing to do to reach the best scores of the Clean Snowmobile Challenge. We worked on principal parts of them to achieve the higher standards. Exhaust, soundproofing, suspension and slides join together; make a new ecological sled.

TRACK AND SUSPENSION – The upgrade that we've done to the suspension is basic, simple and it has a low cost. The modification is basically to rearrange the suspension's geometry to make it work better. With this improvement, the snowmobile gets a better power transfer and an increase comfort on the sled. These pieces are installed on the swinging arm of the suspension. It stops the movement of the arm to couple the two parts of the suspension. However, this modification affects the total stroke of the suspensions shocks. So that give a better agreement and handling to the driver. Here is a view of the parts that is installed on the sled's suspension.

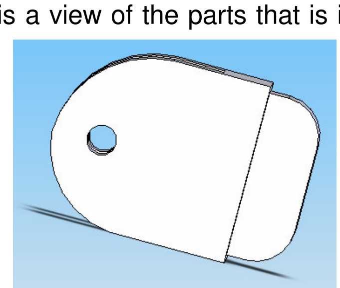


Figure 7: Stopper of the swing arm

These parts are basically made of rubber. All that we've done is to put a piece of a very smooth rubber on the genuine part. Smooth rubber is used to the impact of the swinging arm on the stopper of the suspension.

In other way, the fabrication of the sprocket-wheel is not made one by one. The tolerances are not the same for every pieces. It's why we decide to evaluate the alignment and the eccentricity. The analyze demonstrated that the sprocket-wheel eccentricity is offset of 1/8 inches. So that told us that the power was not correctly transmitted and the major part of it was giving by the chain case side. By machining the sprocket wheel, we rebuild the eccentricity. That's going to adjust the force propagation on all the sprocket wheel and give to the track a better transmission movement. We also had to look at the wheels on the track. The wheels present on the tunnel affect friction. We saw on the slides that the wheels gave to the tracks a wave movement. So at every time that the track pass a wheel, that gave shocks on the slide and it use prematurely. It directly connected to friction and the engine power. By measuring the groove presents on the slides, we find that the entire wheels diameter was 1/8 inches higher then the slides dimensions. So the machining of them gave a better contact of the track on the slides and reduces friction.

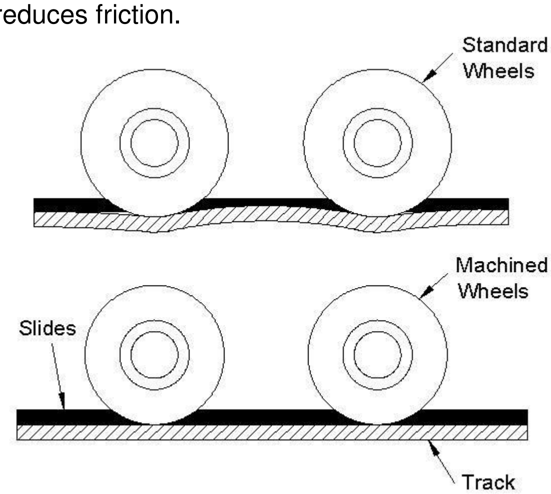


Figure 8: Friction caused on the slides due to the larger diameter of the wheels.

The wheels bearings could be change too, we change them for new sealed bearing. Finally, the friction quality of the bearings can be change too, to avoid friction and give the wheels a better rolling movement. We change the NSK 6205DU5 for SKF 6205 2RSH.

To conclude our tunnel modifications, we install a Teflon sleeve in the plastic slides. Because we upgrade the contact of the track on the slides by machining wheels, we were obligated to reduce friction between them. We've machined a groove in the plastic slide and insert a Teflon band in.

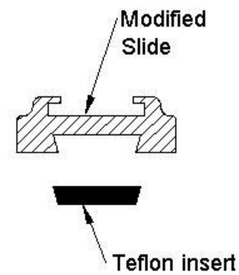


Figure 9: New slide design with Teflon insert.

We chose the Teflon UHMW because it's the materiel who offers the lowest friction coefficient with the steel. That type of technology is already using in high speed snowmobile competition.

MATERIAL 1	MATERIAL 2	Coef. Of Friction	
		DRY	Greasy
		Static	Sliding
Bronze	Steel		
Copper	Copper	1	
Glass	Glass	0,9 - 1,0	0,09-0,12
Graphite	Graphite	0,1	
Graphite	Steel	0,1	
Iron	Iron	1	
Nickel	Nickel	0,7-1,1	0,12
Nylon	Nylon	0,15 - 0,25	
Platinum	Platinum	1,2	
Plexiglas	Steel	0,4 - 0,5	
Polythene	Steel	0,2	
Silver	Silver	1,4	
Steel	Brass	0,35	
Steel	Cast Iron	0,4	
Steel	Graphite	0,1	
Steel	Zinc	0,5	-
Teflon	**Steel**	**0,04**	**0,04**
Teflon	Teflon	0,04	0,04

Table 2: Coefficient of friction table for different materials. [11]

So all those small modifications are going to reduce the gas consumption, pollutant emissions and add more power for the acceleration and eventually add pleasure to the ride.

EMISSIONS

In a perspective to improve the efficiency of the two strokes engine and reduce the bad effect of the combustion, several things on the original conception needed to be changed. The big default of this type of engine is the circulation of the air-fuel-oil mix in general. This mix is created in the base of the engine and it moves in the top of the cylinder by a difference of pression generated by the displacement of the piston. To permit at this mix to move, a duct between top and base is present. This configuration is the principal cause of the bad output of this kind of engine. A part of the mix can go directly in the exhaust port before to be burned. In the figure below, we can see all the path of the mix.

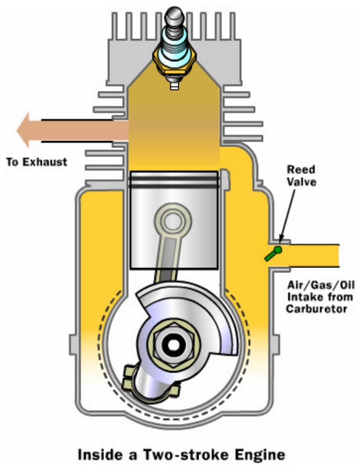


Figure 10. Original two-stroke engine

In comparison, the four strokes engine has a configuration that helps to reduce oil to entry in the combustion chamber. The oil is isolated in the base of the engine. Only the air-fuel mix circulates over the piston. When the mix is compressed and burned, the result is cleaner then two-strokes. This principle prevents a big part of the pollution and it is recognized in the industry.

In this optic, the two-stroke engine equipped with this technology must be interesting and promising. At the first view, several things needed to be changed to realize this modification. Firstly, to stop the exchange between base and top, the duct must be eliminated. Install walls to separate the two parts are a good solution. However, this change has a big consequence on the functionality of this engine. When the piston moves down in the cylinder the air present in the base can not transfer toward the top and a big pressure is built. The simple solution to correct this situation is to install a valve to control the exchange of pressure.

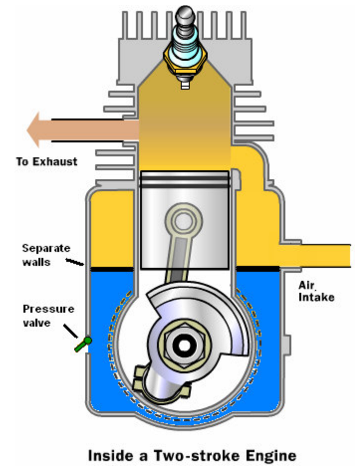


Figure 11. Modified two-stroke engine

Secondly, with this modification, the engine can not blow his air perfectly because the pressure originally created in the base is evacuated outside engine by the valve. Without this difference of pressure it is not possible to do entry air in the top of the cylinder only with the displacement of the piston. The air must be bringing to the engine with a good pressure to reproduce the original effect. (This point is explicated in the supercharge section.)

With these changes, the engine reproduces in part the characteristics of the four-strokes. The air-fuel mix circulates only in the top of the cylinder and the oil stay in the base of the engine. The circulation of the oil is also modified to respect the changes. We only create a circulation system to avoid pressure and temperature raise. In addition to the pump, a radiator have been place under the tunnel.

Supercharger- With changes made on the engine, to bring air to the engine is now necessary. Many solutions exist on the market. A turbocharger or a supercharger is the simplest solution to do this. However, their way to work is very different. In the case of the turbocharger, it is the exhaust flow that drives all the system and this flow must be very important to obtain the reaction. Another point to consider, it's the fact that system it's very expensive and difficult to implant it on an engine. A part of the exhaust need to be changed and an intercooler and oil system is absolutely necessary for a good operation. Finally, the big disadvantages of the turbocharger are the presence of a lag time at each beginning of the cycle and it doesn't works on all rpm of the engine.

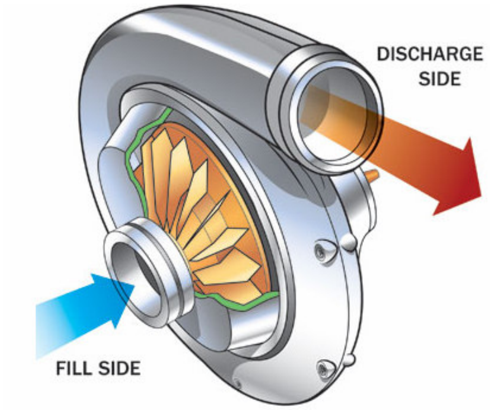


FIGURE 12: SUPERCHARGER

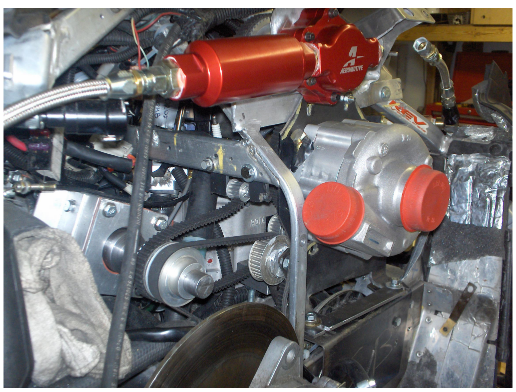
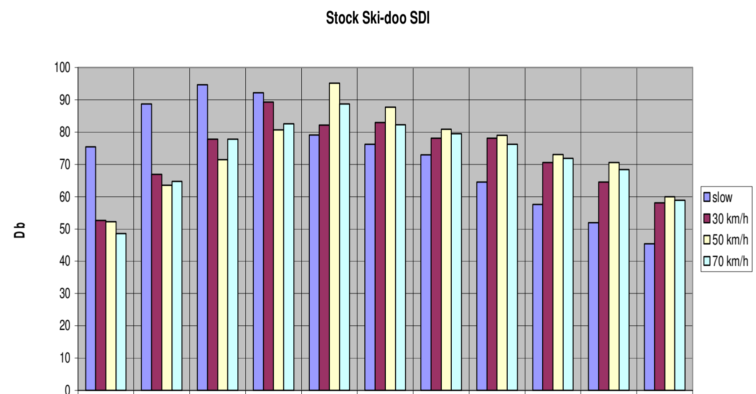


FIGURE 13: SUPERCHARGER SET-UP

Noise Reduction

The noise produced by the snowmobiles is one of their major drawbacks. It can bother the people living near the trails and can be potentially harmful for the snowmobilers themselves. That is why the noise reduction is one of the main goals of the CSC. We can achieve this goal using many different methods. We have used two separate systems to ensure that our modified sled would be quieter than the original version. We fabricated a totally new exhaust system that as a good reduction of noise without restricting the exhaust gas and insulated the motor compartment with a new sound damping material.



	16	31,5	63	125	250	500	1000	2000	4000	8000	16000
slow	75,4	88,7	94,7	92,2	79,1	76,2	72,9	64,5	57,6	52	45,4
30 km/h	52,6	66,9	77,9	89,4	82,2	83	78,2	78,2	70,6	64,5	58,2
50 km/h	52,3	63,6	71,5	80,7	95,2	87,7	80,9	79	73,1	70,6	60
70 km/h	48,6	64,7	77,8	82,5	88,7	82,3	79,5	76,2	71,9	68,4	58,9

Hz frequency

Table 3. Larson-Davis stock Ski-doo SDI sound test

As we can see, some of the sleds could not get in the park due to their high sound levels (higher than 81,9). We can also get our objective to beat an 80,25 dB(A) level at 50 feet with our combined modifications. Here are the first data we collected on a stock sled, a Ski-doo SDI 2005 MXZ Rev from Bombardier. All measurements are also made 50 feet away from the passing sled.

EXHAUST SYSTEM – We can see that the exhaust system of the snowmobile can help reduce the noise a lot. In our approach to keep maximum engine performance, we decided to use dissipative silencers. They create less pressure drop, which ensure a great exhaust gas flow. We have also perforated the inner pipe with holes varying in sizes and lengths. This helps silence various frequencies of noise. Our silencers are filled with ceramic fibers that absorb the sound waves when they come in contact with it. The following chart shows the decibel reduction in function of the frequency for a dissipative silencer. However, this chart does not take into account the variations in the hole patterns but is relatively accurate.

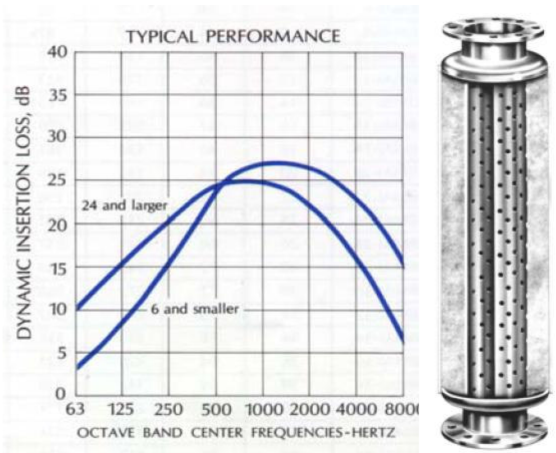


Figure 14: Sound reduction of a dissipative silencer. [14]

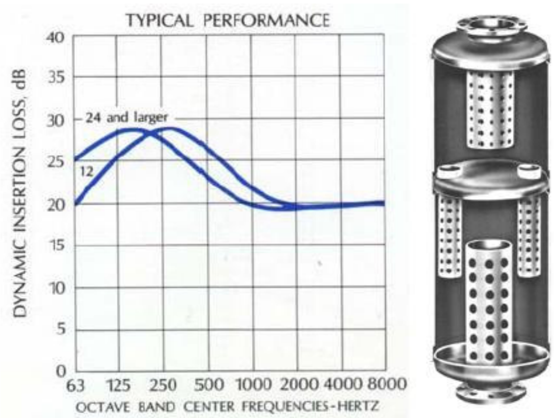


Figure 15: Sound reduction of a reactive silencer. [14]

We can also see that the reactive silencer is much more effective at our working frequencies. However, it creates a lot of pressure drop in the exhaust gas, which brings a loss of power and performance.

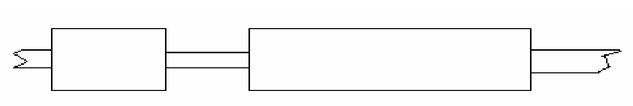


Figure 16: Basic schematic of our modified exhaust system.

Due to the lack of space of the Rev platform from Bombardier, we had to find a new way to build our system. Using the modified tuned pipe, we made the exhaust pipe pass under the motor compartment and then split the pipe in two to install our two dissipative expansion chambers under the two footboards. This way, we where able to maximize space usage and keep an aesthetic look.

SOUNDPROOFING – In addition to the sound coming from the exhaust system, a lot of noise comes from the motor itself, the different vibrations and the rotating parts, mainly the pulley and chain transmission. In order to reduce the sound emissions from the motor compartment, we have decided to insulate it completely.

Figure 17: Interior of the right hand side panel.

Sound absorbent – To start off, we closed all the openings on both side panels and around the chassis. We applied a sound-absorbing barrier inside all the panels surrounding the motor and under the hood. This material is made of two layers of polyurethane foam with different densities, joined together by a rubber section. The different densities of foam absorb a wider range of frequencies and help reduce the overall noise. The top foam is also covered with a thin sheet of aluminum to protect the material from heat radiation. It has also a self-adhesive back to facilitate installation.

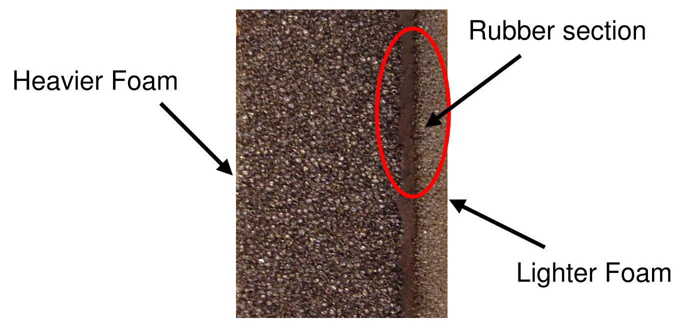


Figure 18: Cross-section of the sound absorber.

The following chart shows the effectiveness level of sound absorption in comparison with the frequency of the noise. In a snowmobile, the sound frequencies vary generally between 50 and 400 Hz. The foam absorber shows good efficiency in this range of frequencies but lacks stopping the lower frequency noises. With the addition of the rubber section, which adds mass to the barrier, we should get improved results at lower frequencies.

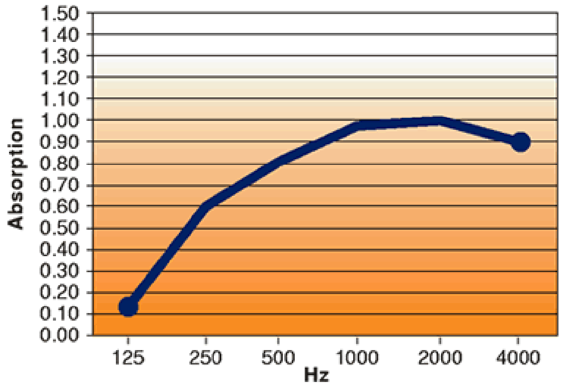


Figure 19 : Efficiency of noise absorption in comparison with the sound frequency. [15]

However, we could not install the sound absorber everywhere because it caused interference with some major component and we were not able close the panels. This was the case with the intake chamber and in the left side panel and the clutch cover. We have also added some foam in the intake box to further minimize the sound coming from the air intake.
Now that the cab is mostly closed and that there is not much air circulation, we could, have over-heating problems. For the motor, which is liquid-cooled, it's not that critical. On the other hand, it can cause problem on the electrical components. Also, the exhaust system could become very hot and damage our sound absorbing material where they are in direct contact. We needed some kind of ventilation.

Figure 20: Picture of last year's hood panel with the nostrils.

The "nostrils" – In order to ventilate the cab, we brought back the idea we came up with last year, the nostrils. Located at the front of the snowmobile, they force cold air in the cab while riding and keep the noise from coming out. This year, we fabricated a completely new fiberglass hood using the standard model with last year's nostril for the basic mold. Also, the fiberglass used as good sound absorbing capacity. Combined with the sound barrier, we will get better results. We remove the lights and close them to get more space in the engine compartment.

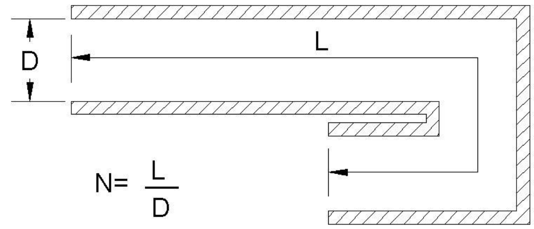


Figure 21: Schematic of the "nostrils". [16]

Because the nostrils created holes in our insulated cab, we needed to make sure the noise would not come out or reduce the amount of noise coming out. To achieve this, we used flexible aluminum tubing to create air ducks. They are shaped in a "U" to create a tight turn in which the sound could come out, but with far less intensity. Because the air will be forced in, this will also help reduce the noise.

After installing the ducks, we applied our sound absorbing material under the hood to cover the ducks, which completed the insulation.

Finishing touches – To finalize the soundproofing, we used self-adhesive rubber strips to seal the junctions between the different panels. This way, we minimize the sound leaks where we have gaps and improve our sound insulation.

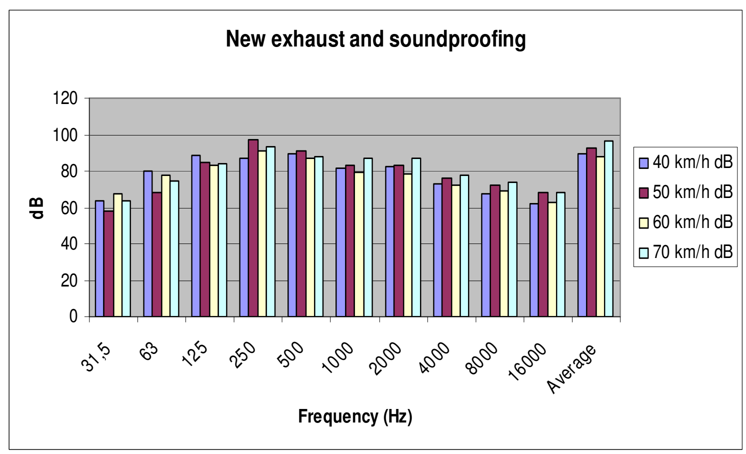


Table 4: Larson-Davis sound test

Miscellaneous

Energy saving versus beam changing.

To get a better energy consummation at the electric level, each part of the electrical wiring. The part that could be change and whom could be able to reduce the energy consummation was the beam in the front of the sled. The original beams were removed and other was found with the same brightness but with less energy consummation.

Security aspect with battery and Haltech in the back of the sled.

To assure a good protection of the Haltech and of the battery, they were placed in the back of the snowmobile. The battery is in a fibreglass case to prevent it from the shock. The Haltech have been place in the back of the snowmobile to prevent the engine it to make it burn. All these parts placed in the back of the sled also permitted a better weight repartition on the sled.

Haltech Utilisation.

The electrical wiring has been modified to receive the Haltech. This one is use to control the injectors with more precision with the help of some captors that collect the information. By this way, it’s easy to calibrate the system.

COST

The overall cost modification of our sled is a little bit high, because of the supercharger. If we remove this item, our system can not be use. In other way, all materials and components can be found in any industrial distributors. The following table shows the different modifications we did with the different price values. These values are taken directly from the technology implementation cost assessment sheet of the CSC 2005.

Table 3: Total cost for modifying our sled.

CONCLUSION

With this year’s design, considering the different systems used on the sled, the way to progress with the two-stroke engine technology is close. Working with an electronic direct fuel injection, improved exhaust systems and making a good sound insulation, all the major requirements were achieved to have a truly clean snowmobile. Although, major changes were made on the motor and the look of the snowmobile, to keeping good performances and an edgy design that appeal to the snowmobilers. Team QUIETS already await next year’s competition in order to develop new and advanced systems.

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